

A PROGRAMMED LOADING PROCEDURE FOR
CONTAINERIZED CARGO SHIPS

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THESIS

A PROGRAMMED LOADING PROCEDURE FOR
CONTAINERIZED CARGO SHIPS

by

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June 1975

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T168485

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Programmed Loading Procedure for Containerized Cargo Ships		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis June 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Tran Quang Thieu		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE June 1975
		13. NUMBER OF PAGES 98
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Logistics Containerization Sealift		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A programmed loading procedure for containerized cargo ships is developed. The model requires input information on the containers to be loaded, the ship's design and hydrostatic properties, and the specific order of port calls to be made in the voyage. The purpose of the programmed procedure is to minimize time		

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The procedure is presented in simple flowcharts and in a detailed FORTRAN IV program. An illustration, which was made as realistic as possible was given and the complete computer printout are attached.

A Programmed Loading Procedure for
Containerized Cargo Ships

by

TRAN QUANG THIEU //

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1975

ABSTRACT

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I. DEVELOPMENT OF CONTAINERIZATION

In 1929, a new idea was developed in the transportation field. Some of the ships operating in coast-wise and contiguous trade were specially outfitted to carry the trucks, trailers and railroad freight cars. Unfortunately, the great potential of this concept was not fully developed due to the lack of standardization. It was not until the mid-nineteen fifties that the next step in the development occurred. Ships were specially designed to carry standard containers. Cargo was stuffed into containers before ships entering the port. Loading and unloading became much more easy, and in the nineteen-sixties containerization was fully developed. Common cargo containers were fully transferable among the various modes of transportation. However, ships were the most important container carriers; in 1966 the first fully-containerized ship entered into the foreign trade market, and later on, the second generation American containerized ship, the LANCER class, commenced operations in 1968-1969.

II. THE PROBLEM

Generally speaking, when containers have been assigned to a specific ship the following factors must be considered.

a. Proper grouping of a consignee's cargo and container accessibility in the marshalling yard.

b. The order of the port calls in the voyage, i.e., containers must be stowed in such a way that there should be no overstay of cargo for a later port over cargo for an earlier port call.

c. Special stowage requirements for hazardous types of cargo or reefer containers requiring access to electrical outlets.

d. Arrangement of weights to meet the ship trim, list, and stability requirements.

Satisfying all these conditions simultaneously becomes a very complex task when there are several loading ports in the voyage. Years after the beginning of containerization, there remains to be developed an effective load planning procedure that can handle all factors. The actual methods now being used vary from company to company. Most of them are manual and based on "trial and error" procedure. They are all time-consuming and consequently leave something to be desired.

III. INTRODUCTION OF A PROPOSED PROCEDURE

In the past, the old "trial and error" methods were more or less adequate to handle the problem. Now that larger ships are being built, changes must be made in order to promote more efficient use of the investment in a vessel. In general, our objective is to reduce the time in port of a ship for loading and unloading. The time would be minimized if the unloading does not require extra movement of containers aboard the vessel, and this, of course, is accomplished by avoiding overstay. Certainly all the factors mentioned in the previous section must be met. In short, to minimize the time in port of a ship means to minimize the overstay, subject to loading constraints. With the assistance of a computer, the goal is attainable. In the next chapter a loading procedure is proposed; calculations of ship's trim, list and stability will be introduced in another chapter. The procedure then is translated into FORTRAN IV language and a somewhat realistic illustration with a complete computer print-out will be given.¹

¹This chapter and Appendix A, were based on a previous study by Dewey E. Beliech, Jr.

IV. ASSUMPTIONS

We shall first assume the following conditions for the model.

A. THE CONTAINER

A container is a box containing cargo. All containers are assumed to be the same size for this procedure.

B. THE SHIP

In general it is not required the ship have any special form. However, for purposes here, it will be assumed that the ship has nine different cargo holds.² Holds vary in sizes, but all can be vertically accessed to any place. In other words, the hatches are as large as the holds. This is generally not a restrictive assumption.

C. THE VOYAGE

The order of port calls in the voyage must be specific and fixed. We can assume, without losing generality, that the ship is making a "circle" trip from port-1 to port-n and after that returning to port-1, (not port-n-1). See Figure 1.

It is assumed that containers are unloaded and loaded at each port in the voyage. Also, it is assumed that the number of containers to be loaded at a port will never be

²The reason for assuming nine holds will be explained in the assumptions about labeled cargo mentioned later in this chapter.

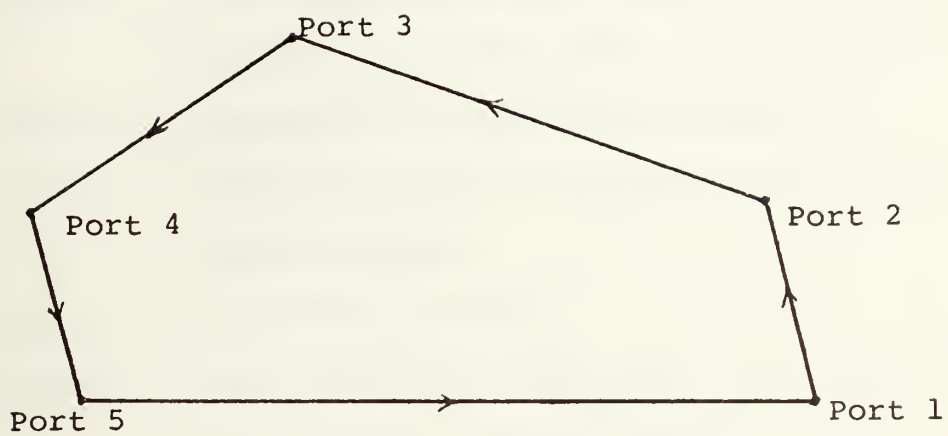


Figure 1: A five port voyage.

greater than the number unloaded at the port. This latter assumption is needed to insure that there is always sufficient space available for loading.

D. THE CARGO

Both labeled and common cargo can be carried, and are classified into the following nine types:

- Type-1³ Explosives.
- Type-2 Inflammable compressed gas (RED GAS) e.g., Butane, LPG, Acetylene.
- Type-3 Inflammable liquids (RED LABEL).
- Type-4 Inflammable solids/oxidizing materials (YELLOW LABEL).
- Type-5 Hazardous articles.
- Type-6 Non-inflammable compressed gas (GREEN LABEL) e.g., Oxygen, Freon, Helium.
- Type-7 Poisonous articles (BLUE LABEL).
- Type-8 Corrosive liquids (WHITE LABEL).
- Type-9 Common cargo.

The first eight types of cargo listed are labeled. Based on Department of Transportation regulations for stowage, most of the labeled cargo types can not be stowed in the same hold. There is no restriction on common cargo. However, type-2 and type-5 cargo are required to be stowed on deck. Refrigerated cargo could be classed as an other type and stowed into a separate hold, however, in this study we

³Type number were arbitrarily selected for programming purpose.

neglect that by assuming as far as refrigerated cargo and containers are concerned, each container is a refrigerator itself, and accessibility to electrical outlets is assumed available around the ship. For more detailed rules of stowage for the labeled cargo, see Appendix A.

V. THE MODEL

A. MATHEMATICAL PROGRAMMING APPROACH

As stated briefly in the introduction, the ultimate objective is to minimize the in-port time of the ship in order to maximize the productivity of the vessel. Port time for a ship is dependent on the number of container movements required aboard the vessel to discharge containers for the port, and to load containers from the port. As previously pointed out, this is accomplished by minimizing overstay. So in terms of a mathematical programming approach, the problem can be stated as:

Objective Function: Minimize (number of overstay containers)

Subject to: - Storage regulations
 - Ship's trim, list, stability requirements.

Conceptually, it appears that the problem can be solved using an Integer-Programming technique. Unfortunately, an initial investigation revealed that for a vessel of even small size, the number of variables would far exceed the capacities of contemporary software and computing machinery. Therefore, it was assumed that pursuing simple mathematical programming approaches would not be fruitful in the short run.

B. HEURISTIC APPROACH

While the mathematical programming is reluctantly discounted, a heuristic approach appeared to be more productive

way of initially grappling with the problem because there exists a set of loading heuristics which simplify the problem. These heuristics, or rules of thumbs, are detailed below. They may not always lead to an optimal solution, but at worst they can be used to get a solution which is more or less optimal. In this sense, the emphasis here is on obtaining workable solutions which more or less minimize overstay. This, of course, is a reflection of the heuristic "philosophy" of problem solving.⁴

1. Loading Heuristics

a. Higher-Sooner

To eliminate, or minimize, overstay the well known "last-in-first-out" procedure is used here. Suppose that containers are being loaded at port-1 (see Figure 1) then all containers destined to port-5 should be at the bottom of each container stack on the vessel. The containers at the top of a stack should be destined to port-2. It can be said that to eliminate overstay, containers for the same POD should be stowed together in the same stack, however, if they cannot all be in the same stack, then the containers for earlier ports should be above the containers for later ports.

b. Higher-Lighter

Ship's stability will be assured if, in any stack of containers, the higher the container is, the

⁴Murray A. Jeisler & Wilber A. Steger, "The Combination of Alternative Research Techniques in Logistics Systems Analysis," Management Technology, May 1963, pp. 68-77.

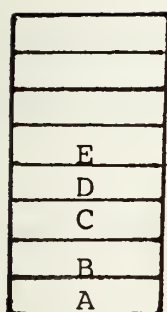
lighter it is. A heavy container loaded below the ship's gravity center tends to lower the gravity center and therefore, increase the righting moment. If not required by regulations, the "higher-lighter" principle is applied here.

c. Left-Right Equality

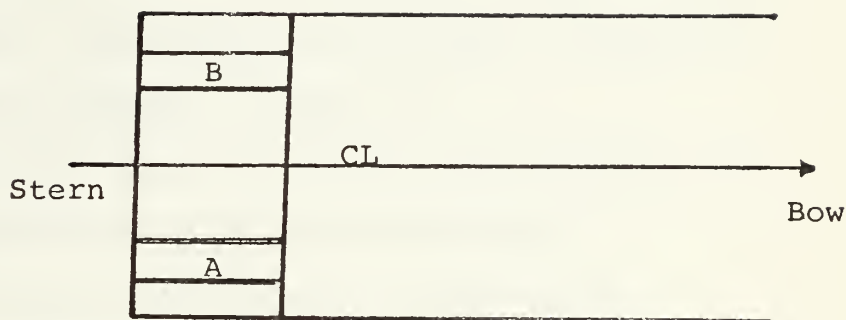
The ship has no list if equal weights are distributed symmetrically with respect to the ship center-line.

d. Heavy-Aftward

Another factor that must be considered is the ship's trim. Usually a slightly deeper aft-draft (trim by the stern) is preferred to keep the ship easily under control. Ship's configurations and ship arrangement vary a great deal. It is almost impossible to set up a general principle regarding distribution of weight along the transverse direction of the ship. However, most ships are constructed such that there are more cargo holds in the forward part than in the aft part. Heavier weights are, therefore, likely to be stowed closer to the stern. Nevertheless, that is not a guarantee. Ship's trim must be calculated before containers are actually being loaded. The difference between aft and forward draft must be within tolerance, or be adjustable by ballasting. The above principles are illustrated through simple examples in Figure 2.



(a)



(b)

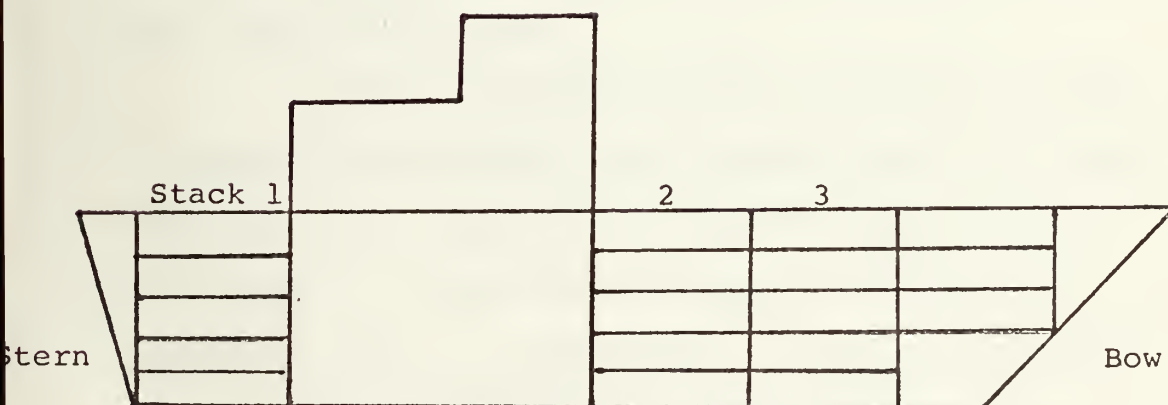


Figure 2: Loading Heuristics

- (a) If all containers are being sent to the same port of destination then $\text{Weight (A)} > \text{Weight (B)} > \dots > \text{Weight (E)}$. If those containers are being sent to different ports then; Container E should be destined to an earlier port than container A.
- (b) Container A and container B should have the same weight.
- (c) Stack-1 should have sufficient weight to counter the weight of stack-2 and 3.

2. The Model

a. System of Coordinates

By using the above heuristics we can develop a loading procedure. For reference purposes, a system of coordinates is first defined. (Figure 3)

Let the XOY plane be the horizontal plane of the lowest deck where containers can be stowed.

Let the XOZ plane be the vertical plane perpendicular to the ship center-line and tangent to the ship stern.

Let the YOZ plane be the vertical plane parallel to the ship center-line and tangent to the left most point of the ship.

Each container storage location, or cell, has an address specified by row, column, and tier. A row of containers is a group of containers having the same Y coordinate. A column of containers is a group of containers having the same X coordinate. A tier of containers is a group of containers having the same Z coordinate.

For example, the container A in Figure 4 has address (4,4,2). In other words, it is at row-4, column-4, tier-2.

b. Load Planning Procedure

Applying the heuristics previously discussed, containers are first sorted into decreasing order of weight. After that, containers are grouped by order of ports of destination and then sub-grouped by types of cargo. This

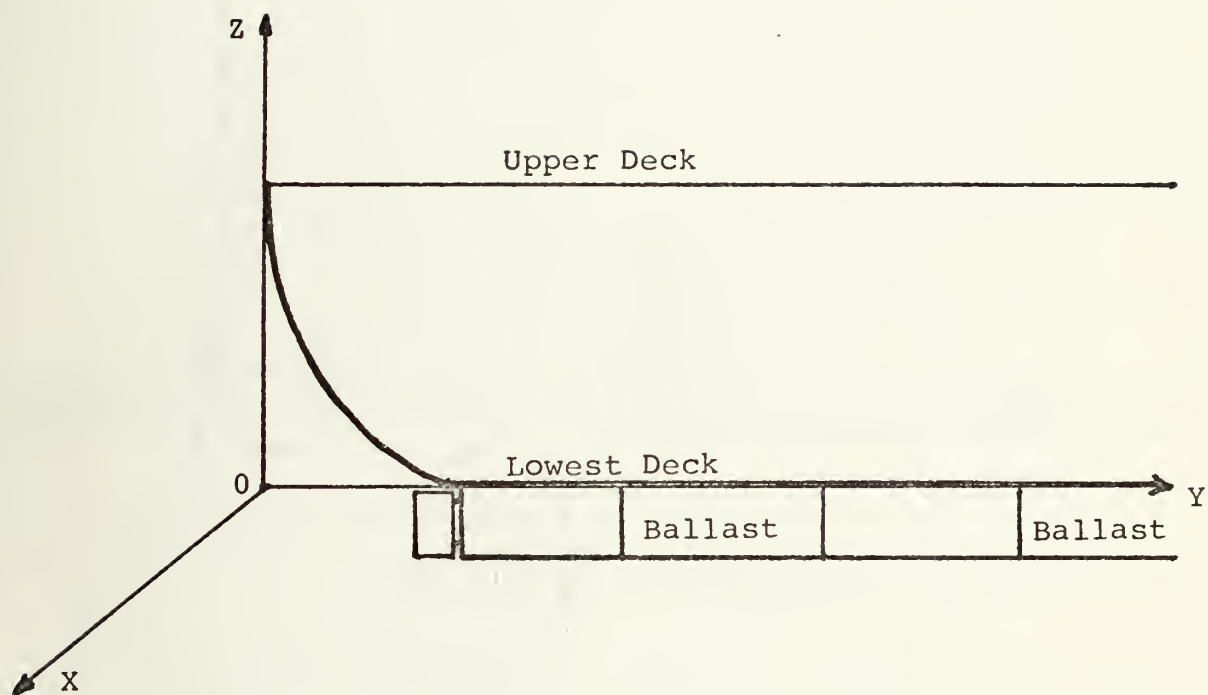


Figure 3: System of Coordinates

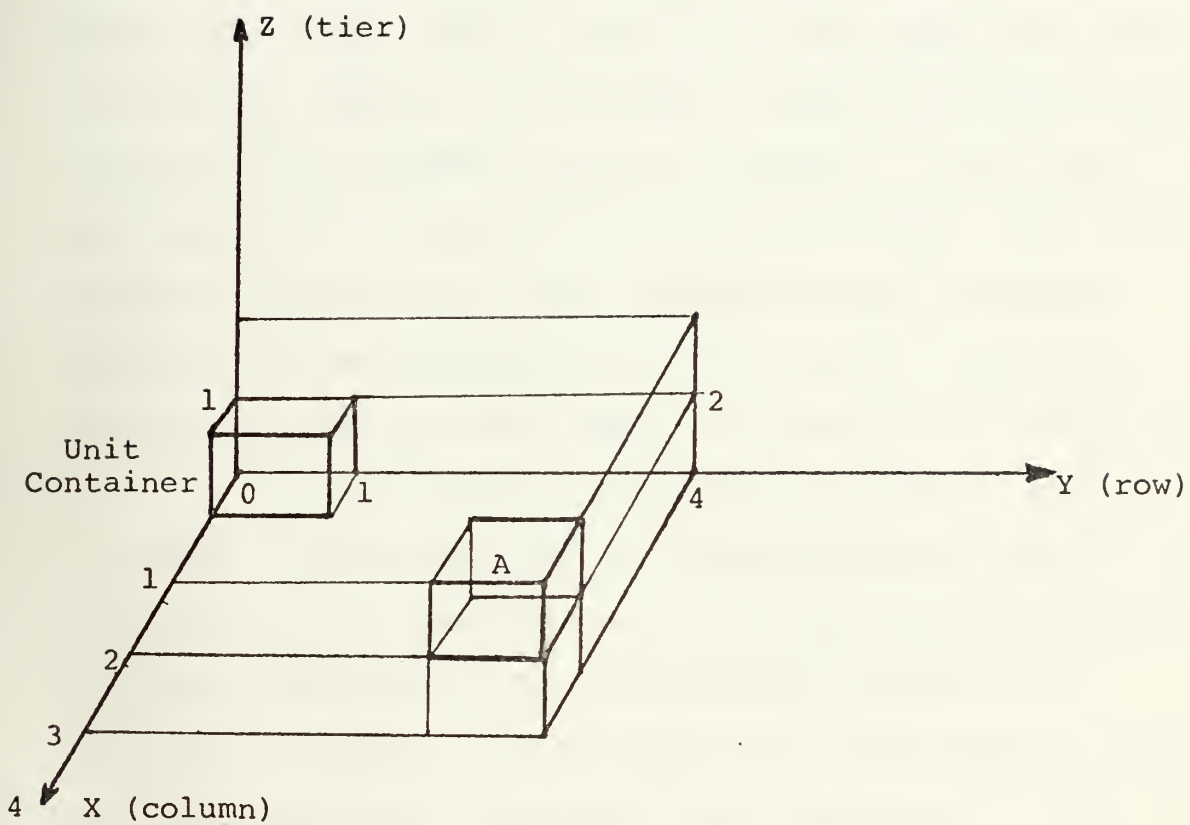


Figure 4: Example Address of a Container

procedure is illustrated by Figure 5. After grouping, containers destined to the last port are assigned to stacks, and assigned to separate holds, depending upon the types of cargo. As an example, containers of type-1 cargo could be assigned to hold (N-1), type-2 cargo assigned to hold (N-2), etc. Now, recall that type-2 and type-5 cargo containers are required to be stowed on deck and common cargo (type-9) can be stowed anyplace; therefore, after type-2 and type-5 cargo containers have been assigned deck spaces, there are "empty holes" left underneath those labeled containers. The holes will be filled up by common cargo containers which have the same (or lower) port of destination.

Ship list is controlled by assigning spaces in a column to the right to the center-line and then assigning spaces in a column to the left, with the same distance from the center line. The total weight of those two columns is generally not the same and a list moment exists, but it is generally slight and can be adjusted by ballasting. If not, stacks can be reassigned before actual loading.

In general, labeled cargo containers are assigned first, following the pattern described above, and illustrated in Figure 6(b). This typically leads to partially occupied stacks, or columns, of containers, and there exist the holes; either underneath or above, which can be filled by common cargo containers.

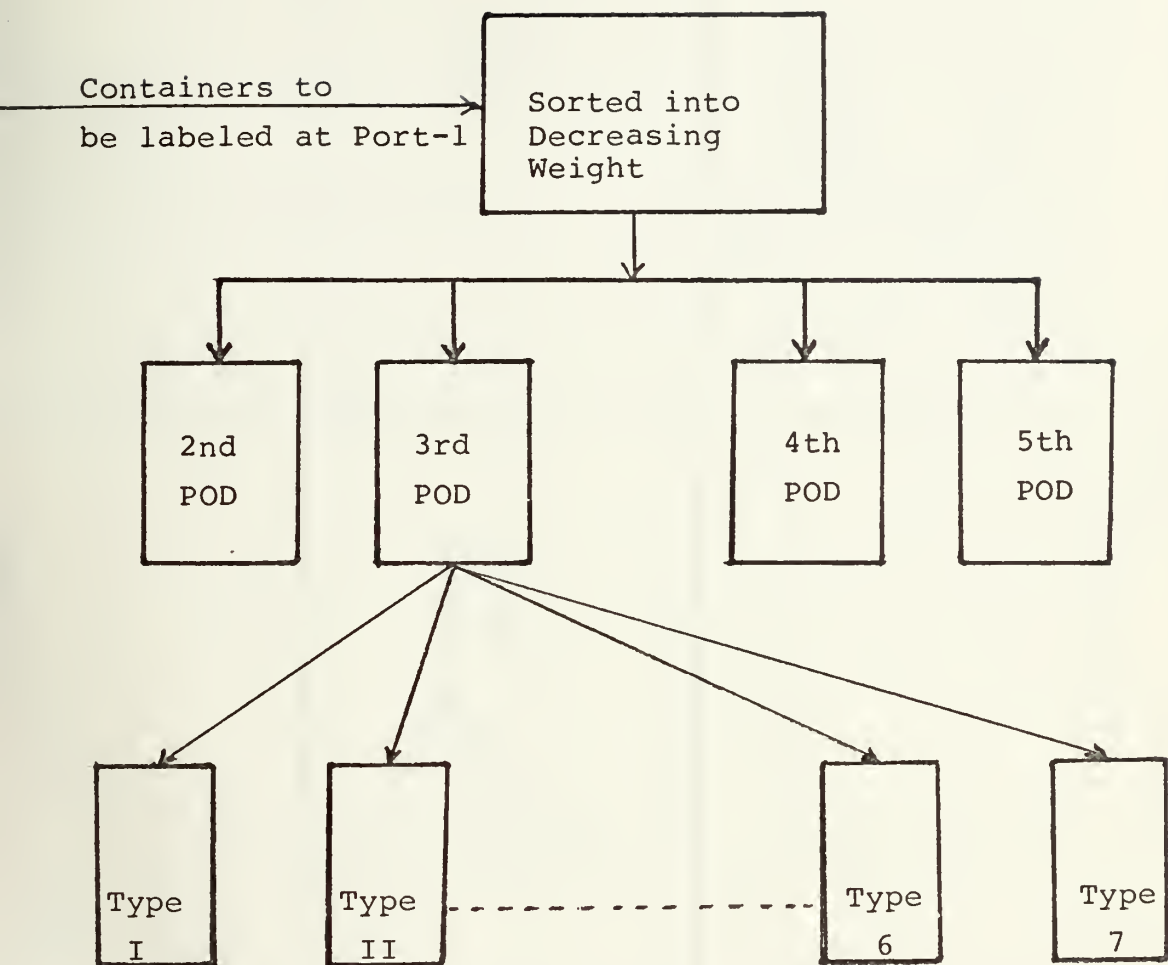


Figure 5: Grouping of Containers

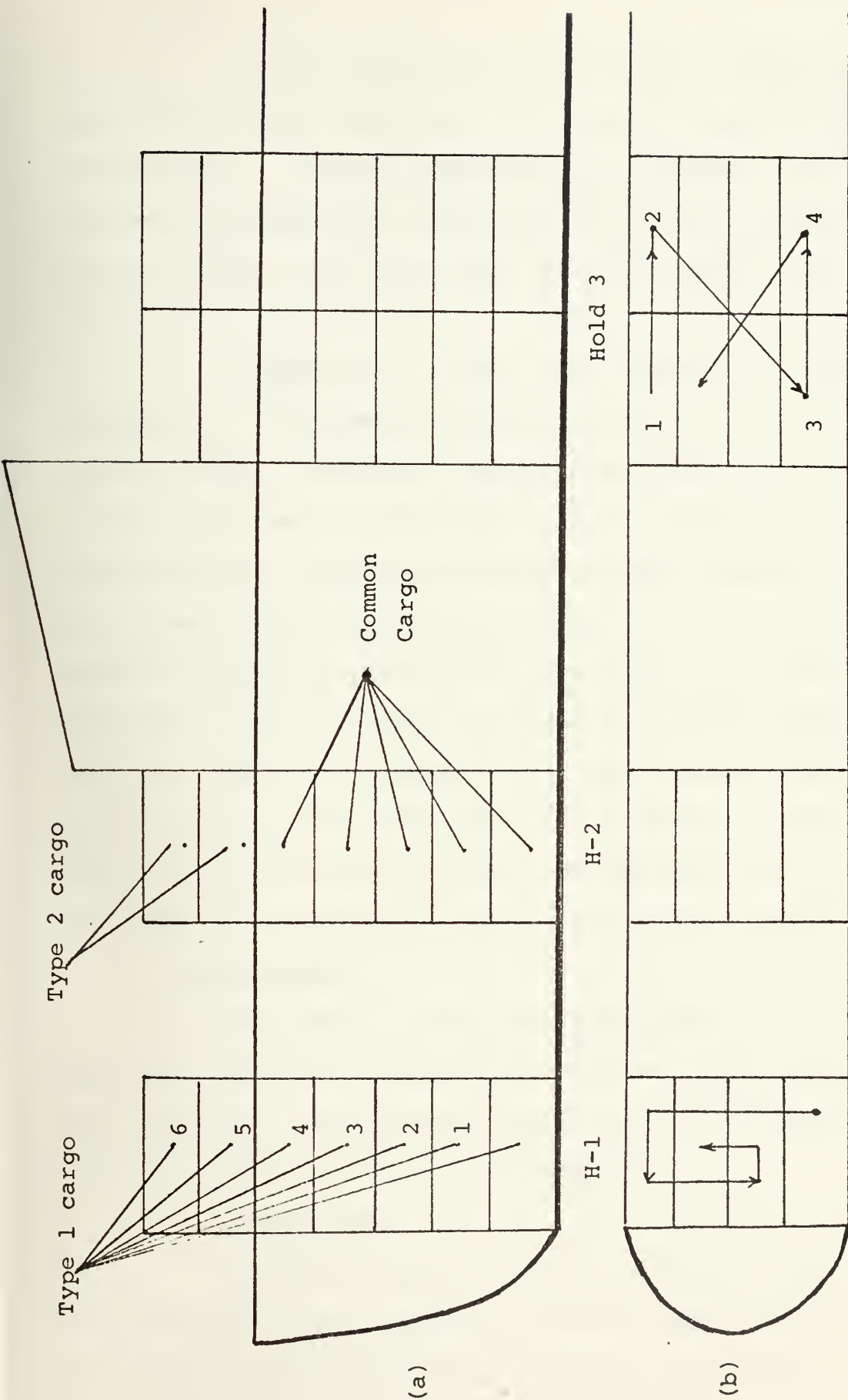


Figure 6: Loading Pattern

Figure 6(a): $\text{Weight}(1) \geq \text{Weight}(2) \geq \dots \geq \text{Weight}(6)$.

Figure 6(b): The order of loading of stacks of containers in hold No 3: 1, 2, 3, 4 ... The order is represented by the path with arrows.

After all containers destined to a POD have been loaded, the containers to the next-to-the-last POD are assigned. The same principles are applied, and addresses assigned to a container only if it has been checked to make sure that there is no overstay. See Figure 7.

Another way to look into the model is illustrated in Figure 8. In general, the heuristics are used for container sorting, grouping, address assignment and matching. In the next chapter these tasks will be explained in detail by flow-charts, computer programs and subroutines. However, some words should be said about the matching. An address can be preoccupied by a container or a ship structure. In this case, the address is automatically rejected, and other addresses will be searched, checked, and matched with the container. This feature allows the model to be independent to ship configuration, and allows the model to be applied at every port in the voyage.

3. Calculations

As mentioned in the above paragraphs, the heuristics here do not guarantee that an optimal solution can be reached and, moreover, ship trim and stability must be calculated to assure that the loading is acceptable.

a. Ship Trim

The inclinations in the transverse direction are measured by the difference between the forward and the aft drafts. This difference in drafts is defined as trim.

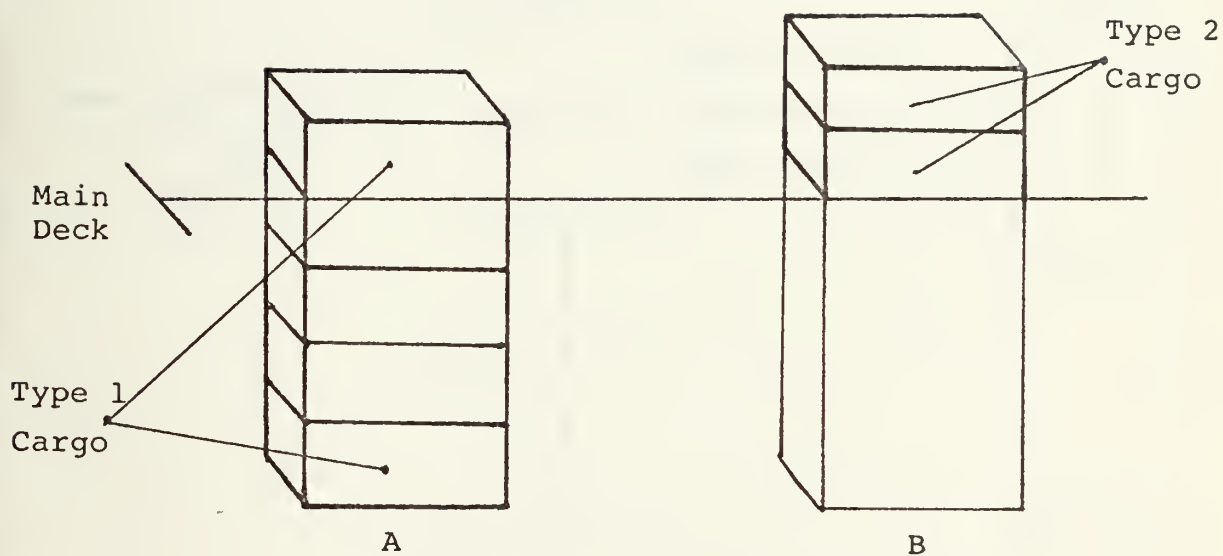


Figure 7: Partially Occupied Stacks of Containers

A: above hole

B: underneath hole



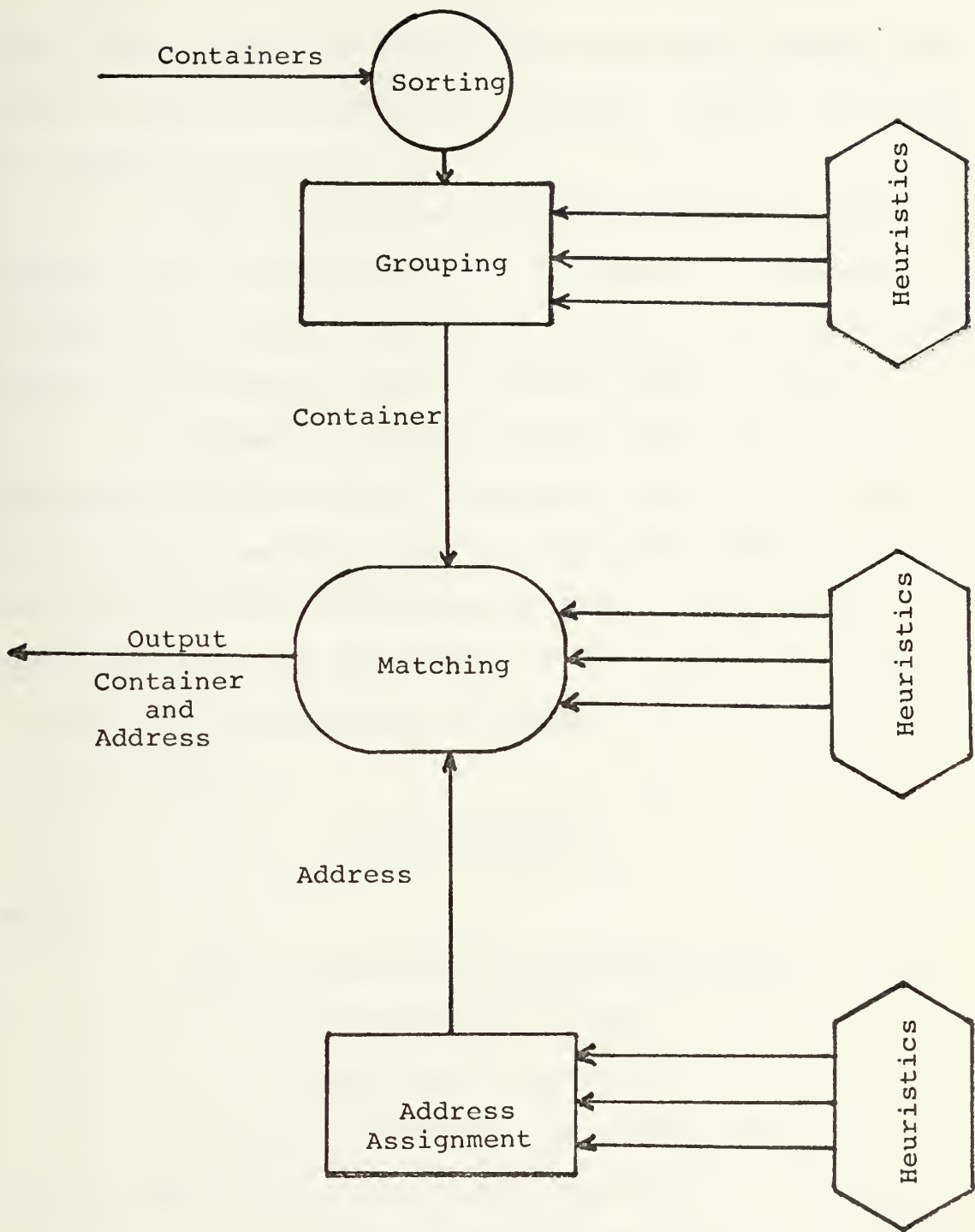


Figure 8: Matching of Containers and Addresses by Selected Heuristics

Where the draft aft is greater than the draft forward, the ship is said to be trimmed by the stern, otherwise the ship is trimmed by the bow.

When a container is loaded onboard, the trim changes, and the change of trim is defined as the change in difference between the drafts forward and aft. To calculate this change we need to define some new terms:

- Moment to change trim one inch, MTI, is the moment required to produce a change of trim by one inch. This value varies depending upon the displacement of the ship and therefore, upon the mean draft. It is often found as a curve in the "Curves of the form."⁵ When such a curve is not immediately available, MTI can be computed by the formula:

$$MTI = \frac{BM' \times W}{12 L} .$$

Where:

BM' = longitudinal metacentric radius (in feet)

W = displacement (in ton)

L = ship length (in feet)

- Center of flotation (CF): The geometric center of the waterline plan is called the center of flotation. For ship trim, it inclines about an axis through the center. For practical purposes, flotation center is assumed at midship or at a point with a distance d from midship; where

⁵NAVPERS 91067, Principles of Stability in Ship Loading, page 69, Bureau of Naval Personnel, 1949.

d is the average distance of distances from the midship to the points on the locus of flotation center.

Thus, if a container with weight equal to w , is loaded at a distance t from CF, the change of trim is:

$$T = \text{Change in trim} = \frac{w \times t}{MTI} .$$

and, by the system of coordinates previously defined

$$\text{New draft, aft} = \text{new mean draft} - T/2.$$

$$\text{New draft, fwd} = \text{new mean draft} + T/2.$$

A subroutine to compute these values after each container is assigned to a space is described in the next chapter and is the principal calculation needed to be attached to any loading plan.

b. List and Ship Stability

Experience has shown that the "higher-lighter" and the "left-right equality" heuristics tend to keep ship stability and ship list within limits. Actually, with the same distance from the ship centerline, a right column of containers which are assigned first, is likely to be a little heavier than a left column because the containers are sorted into decreasing order of weight. However, this list moment is assumed negligible for practical purposes, and can be adjusted by ballasting. If an accurate list is desired, it can be computed in almost the same manner as ship trim. The same holds true for stability. An accurate computation involves a complicated read-in of the cross-curves and lengthy adjustments.

VI. THE GENERAL FLOW-CHART

In the previous chapter the model has been described by words. In this chapter it is depicted by a general flow-chart and by FORTRAN IV language in full details. A somewhat realistic example, with five loading ports, 946 containers and the CB-1 containership, is introduced for purposes of illustration.

The general flow-chart depicts the principal steps of the loading plan. First of all, data involving the ship, the voyage, and the containers are read by the program. The addresses which are already occupied either by containers or by ship objects, are registered. Containers are then sorted into decreasing order of weight, grouped by ports and types. The containers already on-board are listed with their addresses. Ship trim affected by those containers is computed and stored.

Next, new containers are selected, assigned addresses, ship trim is computed and accumulated. The addresses of all containers are then printed as a manifest. If any labeled container is not in a proper hold, or if any one overstowed, then its serial number and characteristics are printed out for human interference. Unoccupied addresses, if any, are also listed in relative port order according to containers partially occupying the stacks.

To carry out these tasks, a main program is used with four subroutines. These subroutines are generally described as follows.

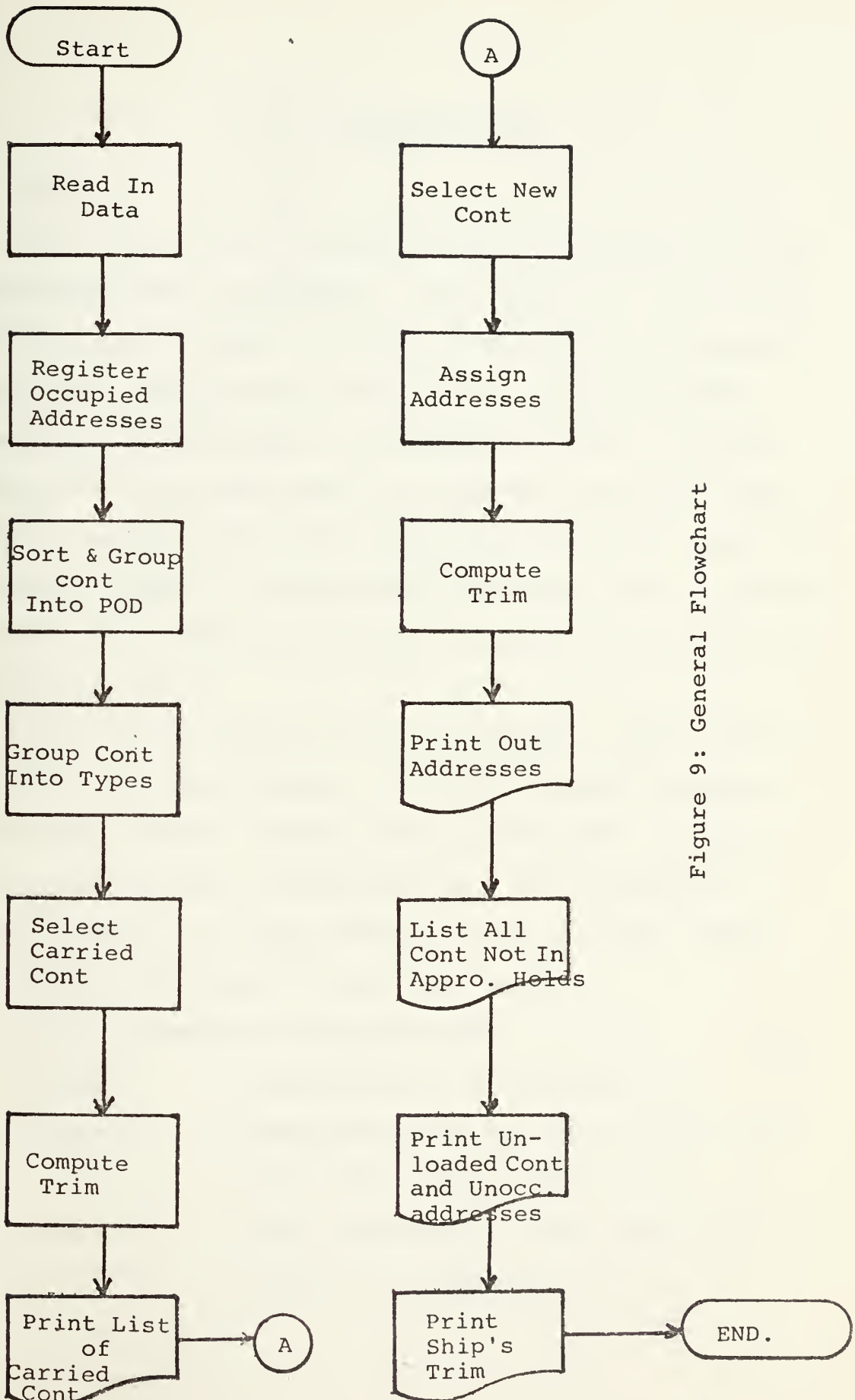


Figure 9: General Flowchart

VII. THE SUBROUTINES

A. SORT

Subroutine "Sort" is used to sort the containers into decreasing order of weights. Data related to a container include: serial number, port of loading, port of destination, cargo type, gross weight, and if already loaded, row-column-tier-address. The weight is used to compare containers with each other; the heaviest container, with all its related data, will be moved to the first place of computer storage. In any later processing, such as address assignment or manifest listing, the heavier containers are considered first.

The data are read by the main program. Following is the list of variable names. Note that "NCONT" includes containers already loaded, "dummy containers", which are merely ship-objects having addresses but no weight or serial number. In fact, NCONT is equal to total number of possible addresses on the ship.

List of Important Variable Names

ICOL(I)	= Column address of container (I).
IPDEP(I)	= Number assigned to a port on the route where the container was loaded.
IPARR(I)	= Number assigned to a port where the container is destined.

IROW(I) = Row address of container (I).
ISER(I) = Container (I) serial number.
ITIER(I) = Tier address of container (I).
ITYPE(I) = Number assigned to the type of cargo
 stuffed inside the container.
WEIGHT(I) = Gross weight of container (I).

A number of variable names, such as NC, WES, are defined internally, they are used only as temporary storage and do not have any special meaning. For a complete variable name list, see Appendix B. The subroutine is listed in the "Computer Program" Appendix.

B. SUBROUTINE POST

The most important and complicated subroutine is "POST". It is used to assign newly loaded containers. It checks all requirements, all constraints posed by regulations and loading heuristics.

First, a general flow-chart is illustrated in Figure 10. As said before, containers are grouped by types of cargo. The main program has specified the appropriate hold for each type of labeled cargo. This subroutine's first step is to check if the hold is full. If it is full, containers will be stowed in a common hold for manual inspection. The program does not determine in which case stowing is tolerated and in which case it is not. If the appropriate hold is not full, the next address in a well-defined sequence will be offered to the container. The matching

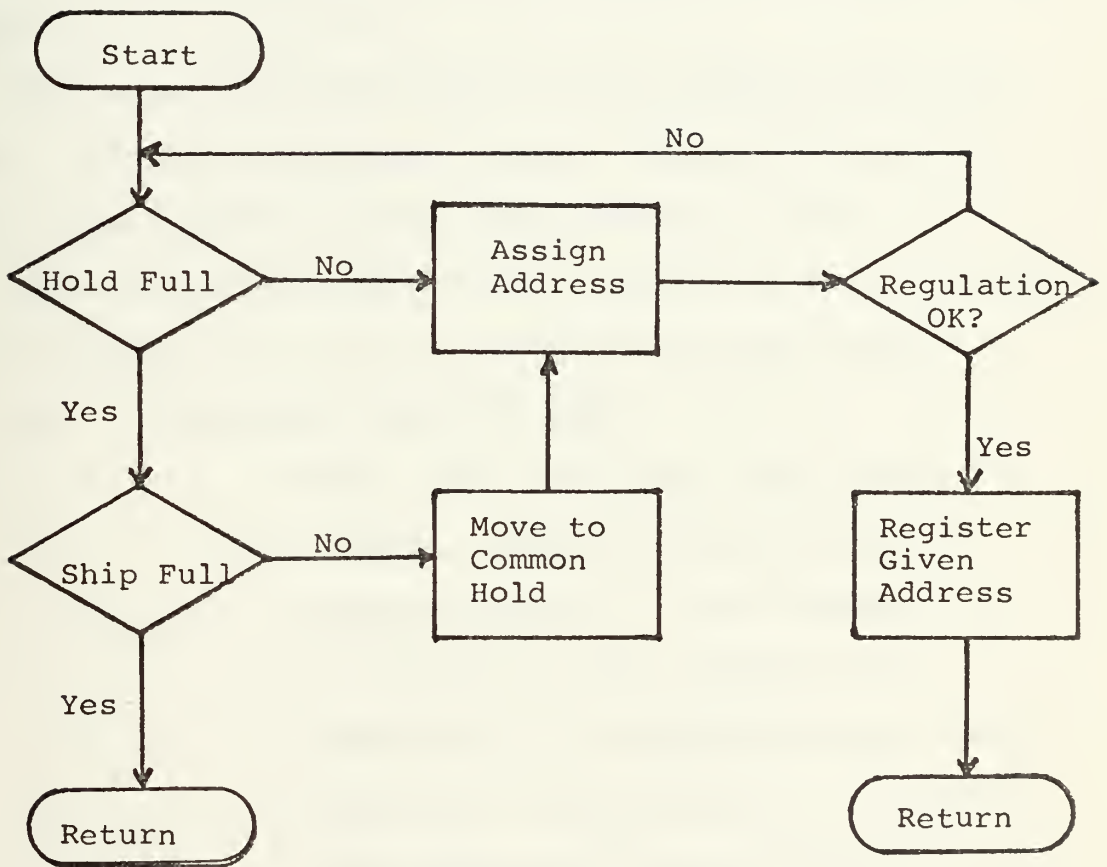


Figure 10: Flow Chart, Subroutine "POST".

will be checked against regulations and if compatible, the address will be registered and returned to main program.

If an address is not acceptable, the next address will be examined. The "next address" is defined as the same row, same column, one-unit-higher tier.

If the new tier address is greater than the maximum, then the new address is one-unit-forward row, same column, tier = 1.

If one-unit-forward takes the row address out of the hold, then the new address is most aftward row, symmetric with respect to C/L of old column address, tier = 1.

The data for "POST" are also read by the main program. The following is a list of important variable names.

List of Important Variable Names

- | | |
|----|--|
| K | = Order of a port under the loading process, where the loading port is assigned number 1. The variable K is relative to the loading port, therefore it is different from IPARR(I) which is a constant while K varies. The loading port can be any port on the route. |
| L | = Index assigned to a hold where type-L cargo is stowed. |
| JC | = Column address under processing. |
| JR | = Row address under processing. |
| JT | = Tier address under processing. |

divided into ten segments, each segment as a linear function of displacement. (AA,BA), (AB,BB),..., (AJ,BJ) are ten ordered pairs of ten points on the draft curve, and (AA,CA), (AB,CB),..., (AJ,CJ) are ten points on the MTI curve. The coordinates of those points are read by the main program and transmitted to "CURVE" through "TRIM".

For a general curve, the coordinates of those ten points are: (XO,YO), (XI,YI),..., (X9,Y9). See Figure 11.

In addition to the variables mentioned above, the following variable names have been used in the subroutines, "TRIM" and "CURVE".

List of Variable Names

A	= Container position and equals row address.
CL	= Container length, in feet.
DIFF	= Difference of mean drafts after a container is loaded.
DISP	= Displacement.
DRAAFT	= Aft draft.
DRAFWD	= Forward draft.
SHLGTH	= Overall ship length, measured by number of rows of containers.
SHMEAN	= Mean draft, in feet.
SHMTI	= Moment of trim by one inch.
T	= Total trim when a container is loaded.
W	= Gross weight of a container being loaded.
D	= Distance from midship to flotation center, positive if C.F is forward of midship, negative otherwise.

BAL1 = Distance from gravity center of aft ballast to midship. Note that if there are more than one aft ballasts, then the gravity center is the center of all ballasts.

BAL2 = Distance from gravity center of forward ballast to midship. See above note.

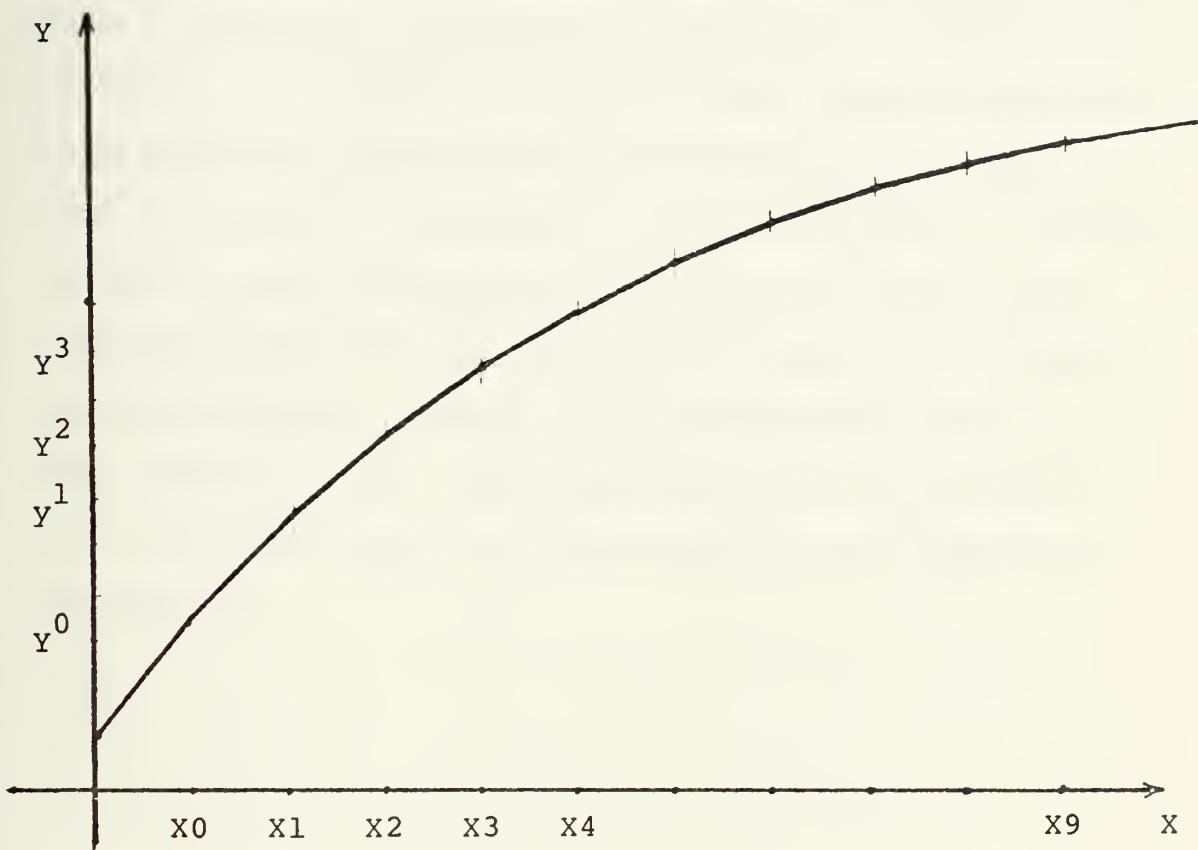


Figure 11: Curve Estimation

VIII. THE MAIN PROGRAM

The main program has been generally depicted by the flow-chart illustrated in Figure 10. Although every statement is important, no attempt is made here to explain each statement. A complete list of variable names is attached in Appendix B, and some brief explanations are integrated into the program to describe its main functions. A numeric example in the next section is used as an illustration. A careful observation of results will help to understand the main program. However, it is recommended that the main program be read both before and after the illustration. It also should be checked during each computation explanation.

IX. ILLUSTRATION

Here is an example which is somewhat close to reality. Data for a C.B-I cargo vessel is used and we suppose that the ship is making a route from LOS ANGELES to SAN FRANCISCO, TOKYO, HONG KONG, SAIGON and then return to LOS ANGELES. There are five ports, NP=5, and the ports are numbered in Figure 12.

It is also supposed that containers are being loaded on the ship at San Francisco, thus, the number of loading port is 2, NLOADP = 2, and containers to SAIGON will be loaded first because there are no containers destined to Los Angeles. The ship can handle 8 columns, and 6 tiers of containers (4 tiers under the main deck). There are totally 2640 addresses but only 946 containers can be loaded. The other addresses are permanently occupied by ship objects. The data mentioned above are read by statement 004.

The total number of rows (equals 55 in this case) are divided into 9 holds. For this example the numbers of rows in the holds are: 9,2,6,2,12,2,6,2,8. Note that these figures can be rearranged, i.e., any number can be zero or any two or more holds can be combined into one hold for stowing one type of cargo. These data are read by statement 005 with format (1015).

All data related to individual containers (including dummy containers) are read next by statement 007. These

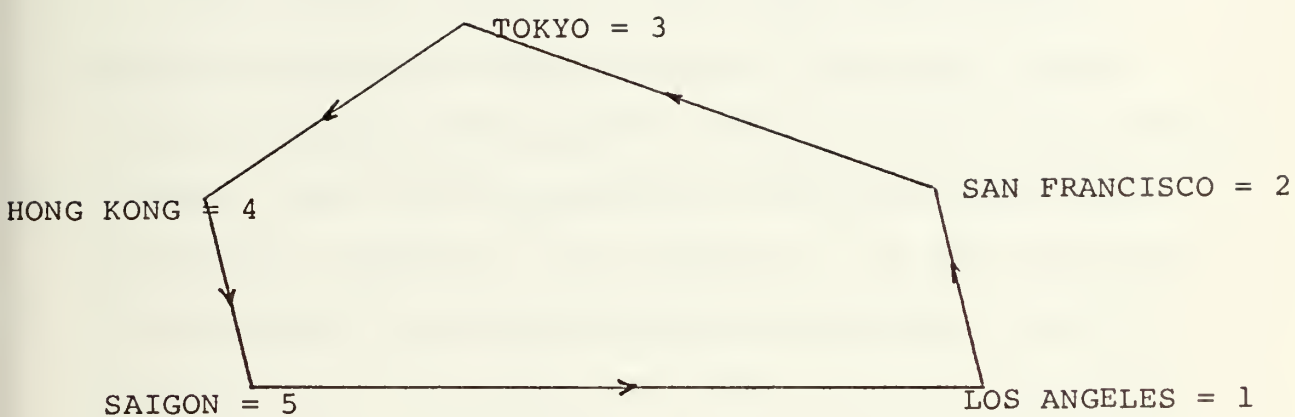


Figure 12: Illustrating Voyage

data are punched on a card, format (I10,315,F10.3,I10,215). For dummy containers and containers which have been already loaded, addresses in row, column, and tier must be specified.

Next, ship data, (displacement, aft-draft, forward draft, ship length by containers, container length in feet, position of flotation center, position of ballast gravity centers, and coordinates of points on the draft and MTI curves), are read.

Not much is necessary to say about "CALL SORT", Initialization, and Registration of addresses, except what we mean by LOG(JC,JR,JT). Suppose that a container(I) is being sent from Los Angeles to Hong-Kong; its port of destination IPARR(I)=4, see Figure 12. At San Francisco, this container has been already been labeled, and also suppose that it is stowed at column JC, row JR, tier JT. Keep in mind that the location LOG(JC,JR,JT) has been occupied by a container to Hong-Kong which is the third port on the route, relative to loading port, San Francisco. In the process of registration, this relative order is needed so that overstay can be prevented. The absolute, unchanged order IPARR(I) of the container is used to compute the relative order; see statements 026,027,028. Note that any dummy container has that relative order equal to NP (latest call port) so that any real container can be stowed over it.

The first computation is to determine the address of the center column. Columns of containers are assigned

from the left most and from the right most to the center-line. For a maximum of 8 columns the sequential column address is: 8,1,7,2,6,3,5,4. That means the right most column, 8, then the left most column, 1, are assigned first. The last column to be stowed is column-4, and we have to determine this number, MAC, before the main program can call sub-routine POST. Depending on whether MAXCOL is odd or even, then:

$$MAC = (MAXCOL + 1)/2$$

or $MAC = MAXCOL/2$ (8/2 = 4, for this example.)

In the grouping process, there is no difficulty to group containers by cargo types. Type-1 cargo containers are considered first. Any container with ITYPE(I) not equal to 1 will be dropped out, and so on. However, it would be a little more complicated to group containers by order of port calls. We can not use IPARR(I) because this variable gives the absolute, unchanged value assigned to each port. What we need is the relative order with respect to the loading port. We start by considering containers of the latest call port. The variable K, the relative order of considered port, and then NARRP, the permanent number assigned to the considered port, are determined and computed. If IPARR(I) is not equal to NARRP, then the container will be dropped out of the grouping process. Statements 034 and 035 compute K and NARRP. The variable K has the sequential values: 5,4,3, and 2, because for the loading port NLOADP = 2, NARRP has the sequential values: 1,5,4, and 3. In this case port-1 is the latest call port.

After all carried containers have been selected and listed on the manifest, the new containers are then assigned. First, the address to the lower-right most aft corner is offered. For this example it is (8,1,1). The address is examined and, in this case, is pre-occupied by ship configuration. The next address is then offered and checked; the step from one address to the next has been explained previously. Actually, the first acceptable address is (7,4,2). See computer print-out page 58.

Based on the order that has been determined by computation, the addresses and related data of all containers destined to port-1, port-5, port-4, port-3 (in that order) are printed. There are no containers from San Francisco to Los Angeles here, therefore, only the headlines are printed.

The last part of the print-out is a summary. First, the boundary of each hold is determined; each container which is in an unacceptable hold, is listed. Sometimes, depending on the nature of the cargo, "sharing" can be tolerated. If it is not tolerated, decisions to relocate or drop-out the containers must be reached before containers are actually loaded.

All addresses and containers are also investigated. Any container which has not been assigned an address, or any address which has not been occupied, are listed. Along with an unoccupied address is the relative order

of the POD of the container which is stowed at the lowest location of the stack on deck. There are addresses unoccupied because there are containers required to be stowed on deck. These containers are for a POD whose relative order is high, therefore, the common containers of other ports can not be used to fill those "lower holes". Again, human interpretation is necessary. In this example, newly loaded common cargo containers destined to Saigon (port-5) which have been assigned addresses somewhere in the same hold should be re-assigned to those unoccupied addresses, and there will be no overstay.

Data related to the containers in the example have been generated by a random number process based on assumption that a certain percent of containers are of type-I, ($I = 1,9$) and a certain percent of containers from a port-J are sent to a port-K. ($K = 1,5; K \neq J$). Certainly overstay depends on the number of containers required to be stowed on deck. With 4%, it is likely that about 1% might be overstowed without manual adjustment.

In the last part of the printout summary are the results related to ship's trim. Note that the weight of water used to balance the ship must be smaller than the capacities of the involved ballasts. This figure is used to identify whether the load plan is feasible. If it is not acceptable, then manual corrections are needed.

For complete results, see the computer printout.

X. FEASIBILITY OF THE MODEL AND RECOMMENDATIONS FOR USE

The model was developed through a heuristic approach, and many assumptions had to be made. As a result, the model's overall capacities are subject to some limitations. The heuristic approach does not always yield an optimal solution. The model assumes that containers are of a single size.

The model does not depend on ship form and ship objects, however, an assumption has been made about the vertical direct accessibility to any address on board. This means that if only one stack of containers under the main deck is to be unloaded, then all containers on the deck, over the hatch, must be removed. In this case, the solution reached may become less meaningful as far as overstow is concerned. However, this problem could be accommodated with multiple-removable-container-sized-auxiliary hatches as shown in Figure 13.

The model is not 100% computerized. Due to a variety of regulations requiring separation of labeled cargo, a ship loaded with all nine types of cargo might not have enough separate holds for each type of cargo; or in some cases, a hold reserved for a specific type of cargo is full. Manual adjustment are also needed in the cases where there is overstow which the program cannot avoid, or in the cases where ship trim, stability, or list is unacceptable.

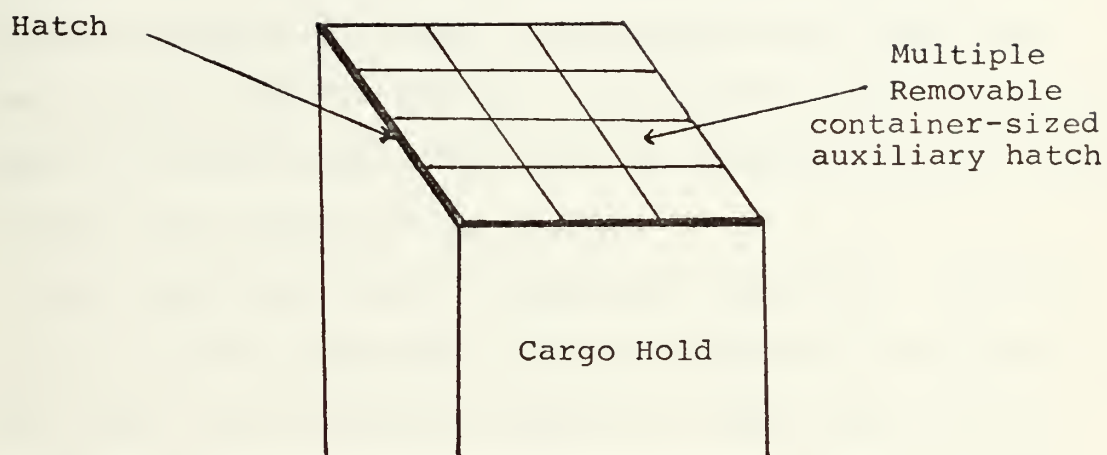


Figure 13: Specially Designed Hatch.

Changing the locations of some container stacks is not very difficult with data available from the computer printout.

The model only shows where containers should be stowed, it does not point out which stack of containers should be loaded first and which one second, etc. If we follow the order printed, the ship might be sunk in port. The loading officer should load stacks of containers in a way such that the ship stay afloat after any container is loaded.

The model can be used in the pre-loading stage. Containers should be arranged in the marshalling area such that they are easy to access. A good solution is to arrange them in the same way as they will be stowed on board, except in each stack the order is reverse.

The last point here is completely technical. To make the model more applicable, all data related to the ship and the voyage can be stored on tape or a data cell, but data related to containers should be punched on cards. Output related to each carried container is needed as input for next loading port, therefore, an extra card output is necessary.

XI. IMPLICATION FOR FURTHER STUDY

A. TESTING AND ANALYSIS

The model has been used with a variety of different data, and results were acceptable. However, the model should be further tested with greater ranges of data by changing the ship, the route, and the generating program, the number of port calls, total number of containers to be loaded, ship characteristics, percentage of labeled cargo, percentage of cargo to each port, etc. Using these variables as independent variables, the model can be tested to provide dependent variables such as number of containers overstowed, number of addresses which must be re-considered, and the number of cases where ship trim is unadjustable. The results could be analyzed by multi-variable statistics in order to draw firm conclusions about the feasibility of the model. The loading program itself requires almost 3 minutes CPU time on an IBM360/67, therefore the process of testing which includes data generating, loading, and analysis, will be costly and time-consuming.

B. MODEL EXPANDING

Only the trim computation has been included in the model. Ship list and stability have been neglected based on the belief that these effects are generally not a problem. Another subroutine should be developed and added to the program, at least for testing and assuring the feasibility of the solution,

The program can be modified to take into account the effect of the hatches on overstay. This development would lead to more realistic solutions.

Like celestial navigation, which provides a better and more accurate position from an estimated position, the model can be developed such that the result after the first loading attempt can be revised and used for the second attempt, etc. As seen in the illustration, the summary has included assignments that must be reconsidered and a number of containers that have not been loaded. The model can be revised such that the program will "automatically" take these considerations into account, reassign some addresses to some containers, and repeat the procedure until an acceptable solution is reached.

The concept of containerization has been in existence for quite some time, but is still an area requiring quantitative research. The model here and its proposed applications are no exception to this.

APPENDIX A

BASIC RULES FOR STORAGE OF CARGO

Type-1: EXPLOSIVES

Must not be stowed with any other labels.

Type-2: INFLAMMABLE COMPRESSED GAS (RED GAS)

Must be stowed on deck.

Cannot be stowed over a red label hatch.

Must be 25 feet from any other hazardous cargo.

Must have the deck house between it and explosives.

Type-3: FLAMMABLE LIQUIDS (RED LABEL)

Must not be stowed in the same hatch with inflammable solids, oxidizing materials, corrosive liquids, poisons, or cotton.

Must not be stowed in the same hold over non-inflammable compressed gases.

Many red label items require between deck storage, therefore no red label is to be stowed in a lower hold or deep tank without checking the regulations.

Must have a full hatch or midship house intervene between it and explosives.

Type-4: INFLAMMABLE SOLIDS/OXIDIZING MATERIAL (YELLOW LABEL)

Must not be stowed in the same hold or compartment as red label, corrosive liquids, poisons, or cotton.

Must not be stowed in the same compartment over non-inflammable compressed gases.

Must have a full hatch or midship house intervene between it and explosives.

Type-5: CORROSIVE LIQUIDS (WHITE LABEL)

Some are permitted under deck storage. General policy is to stow on deck at all times.

Must not be stowed adjacent to or over any poisonous articles or hazardous items.

Must not be stowed on the square of the hatch.

Must have a full hatch or midship house intervene between it and explosives.

Type-6: NON-INFLAMMABLE GASES (GREEN LABEL)

Must not be stowed with explosives.

Must not be over stowed with corrosive liquids, inflammable solids, oxidizing material, poisons, or hazardous articles.

Type-7: POISONOUS ARTICLES (BLUE LABEL)

Must not be stowed in the same compartment with explosives, inflammable liquids, inflammable solids, refrigerated cargo, or cotton.

Must not be stowed adjacent to corrosive liquids.

Must not be stowed over compressed gases.

Type-8: HAZARDOUS ARTICLES

Must not be stowed in any compartment with explosives.

Type-9: COMMON CARGO

Can be stowed any place.

APPENDIX B

LIST OF VARIABLE NAMES USED IN COMPUTER PROGRAM

A = Container position and equals to row address.

BAL1 = Distance from gravity center of aft ballasts to midship.

BAL2 = Distance from gravity center of forward ballasts to midship.

CL = Container length, in feet.

D = Distance from midship to flotation center, positive if CF is forward of midship, negative otherwise.

DIFF = Difference of mean draft after a container is loaded.

DISP = Displacement.

DRAAFT = Aft draft.

DRAFWD = Forward draft.

ICOL(I) = Column address of container I.

IPDEP(I) = Number assigned to a port where the container was loaded.

IPARR(I) = Number assigned to a port where the container is destined.

IROW(I) = Container row address

ISER(I) = Container serial number.

ITIER(I) = Container tier address

ITYPE(I) = Number assigned to the type of cargo stuffed inside the container.

JC = Column address under processing.
 JR = Row address under processing.
 JT = Tier address under processing.
 JL = First tier address on deck.
 K = Relative order of a port under processing.
 KRORIG = Maximum row address of a hold.
 L = Index assigned to a hold where type-L cargo is
 stowed.
 LOG = Address characteristics, zero denotes unoccupied
 address.
 MAC = Midship column address
 MAXCOL = Maximum value of column address
 MAXROW(L) = Number of rows in the hold L.
 MLOWER = Maximum value of tier address, on deck.
 MTIER = Maximum value of tier address.
 NCONT = Total number of possible addresses.
 NARRP = Number assigned to the port under processing.
 NLOADP = Number assigned to the port where containers
 are being loaded.
 NP = Number of ports on the route.
 SHLGTH = Overall ship length, measured by number of rows
 of containers.
 SHMEAN = Mean draft, in feet.
 SHMTI = Moment trim by one inch.
 T = Total trim when a container is loaded.
 W = Gross weight of a container being loaded.
 WEIGHT(I) = Gross weight of container I.
 WATER = Water added in ballasting process.

COMPUTER OUTPUT

MANIFEST OF CARGO CONTAINERS TO PORT NO.1

ORDER OF LOADING PORT ON THE ROUTE: 2

CARGO TYPE 1

SER-NO.	PORT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
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CARGO TYPE 2

SER-NO.	PORT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
---------	-----------------	------	--------	-------------------------

CARGO TYPE 3

SER-NO.	PORT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
---------	-----------------	------	--------	-------------------------

CARGO TYPE 4

SER-NO.	PORT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
---------	-----------------	------	--------	-------------------------

CARGO TYPE 5

SER-NO.	PCPT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
---------	-----------------	------	--------	-------------------------

CARGO TYPE 6

SER-NO.	PCPT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
---------	-----------------	------	--------	-------------------------

CARGO TYPE 7

SER-NO.	PORT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
---------	-----------------	------	--------	-------------------------

SER-NO.	DEP	PORT	CARGO TYPE	8	ADDRESS	ROW	COL	TIER
			TYPE	WEIGHT				
			CARGO TYPE	9	ADDRESS	POW	COL	TIER
			TYPE	WEIGHT				

100251	1	5	5	2.307	31	8	5	CARRIED	CONTAINER
100055	1	5	5	0.526	31	8	5	CARRIED	CONTAINER
100709	1	5	5	0.300	30	1	5	CARRIED	CONTAINER
200120	1	5	5	0.909	30	4	5		
200089	2	5	5	8.810	30	4	6		
200036	2	5	5	5.264	31	4	5		
200021	2	5	5	4.741	31	4	5		
200130	2	5	5	3.884	46	4	5		

CARGO TYPE 6

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100154	1	5	5	6	8.485	32	8	1	CARRIED
100046	1	5	5	6	5.188	32	8	2	CONTAINER
100649	1	5	5	6	3.231	32	8	3	CONTAINER
200149	2	5	5	6	5.820	32	4	1	CONTAINER

CARGO TYPE 7

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100510	1	5	5	7	9.072	38	8	1	CARRIED
100473	1	5	5	7	6.615	38	8	2	CONTAINER
100064	1	5	5	7	5.068	38	8	3	CONTAINER
100816	1	5	5	7	3.580	38	8	4	CONTAINER
100438	1	5	5	7	2.477	38	8	5	CONTAINER
100623	1	5	5	7	0.634	38	8	6	CONTAINER

CARGO TYPE 8

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100846	1	5	5	8	7.491	40	8	1	CARRIED
100293	1	5	5	8	6.863	40	8	2	CONTAINER
100212	1	5	5	8	1.062	40	8	3	CONTAINER
100399	1	5	5	8	0.739	40	8	4	CONTAINER

100375	1	5	2	7.835		10	8	5	CARRIED	CONTAINER
100746	1	5	2	4.486		10	8	5	CARRIED	CONTAINER
100748	1	5	2	2.169		11	8	5	CARRIED	CONTAINER
200052	1	5	2	8.268		10	4	5		
200144	2	5	2	6.076		10	4	6		

CARGO TYPE 3

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ADDRESS	ROW	COL	TIER
100184	1	5	3	3	8.018		16	8	2
100796	1	5	3	3	7.918		16	8	3
100013	1	5	3	3	7.360		16	8	4
100133	1	5	3	3	5.245		16	8	5
100795	1	5	3	3	3.905		17	8	6
100309	1	5	3	3	3.275		17	8	2
100294	1	5	3	3	3.009		17	8	3
100273	1	5	3	3	1.327		17	8	4
100770	1	5	3	3	0.883		17	8	5
100669	1	5	3	3	0.466		17	8	6
200012	2	5	3	3	7.746		16	4	2
200068	2	5	3	3	5.366		16	4	3

CARGO TYPE 4

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ADDRESS	ROW	COL	TIER
100469	1	5	4	4	5.004		18	8	2
100676	1	5	4	4	4.728		18	8	3
100074	1	5	4	4	4.616		18	8	4

CARGO TYPE 5

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ADDRESS	ROW	COL	TIER
100149	1	5	5	5	8.603		30	8	5
100639	1	5	5	5	6.654		30	8	6

MANIFEST OF CARGO CONTAINERS TO PORT NO.4

ORDER OF LOADING PORT ON THE ROUTE: 2

CARGO TYPE 1

SER-NO.	PORT DEP	PORT ARR	TYPE	WEIGHT	ROW	ADDRESS COL	TIER
100761	1	4	1	9.808	7	CARRIED	2
100884	1	4	1	9.230	7	CARRIED	3
100169	1	4	1	8.906	7	CARRIED	4
100119	1	4	1	8.547	7	CARRIED	5
100765	1	4	1	8.525	7	CARRIED	6
100657	1	4	1	7.646	7	CARRIED	2
100103	1	4	1	7.603	8	CARRIED	3
100545	1	4	1	7.415	8	CARRIED	4
100016	1	4	1	6.276	8	CARRIED	5
100668	1	4	1	5.563	8	CARRIED	6
100319	1	4	1	5.500	9	CARRIED	2
100444	1	4	1	5.083	9	CARRIED	3
100001	1	4	1	4.718	9	CARRIED	4
100879	1	4	1	4.672	9	CARRIED	5
100241	1	4	1	4.169	9	CARRIED	6
100507	1	4	1	3.936	7	CARRIED	2
100911	1	4	1	3.558	7	CARRIED	3
100336	1	4	1	3.552	7	CARRIED	4
100565	1	4	1	2.562	7	CARRIED	5
100421	1	4	1	2.121	7	CARRIED	6
100357	1	4	1	1.248	7	CARRIED	2
100662	1	4	1	1.883	7	CARRIED	3
100313	1	4	1	0.846	8	CARRIED	4
100208	1	4	1	0.713	8	CARRIED	5
200146	1	4	1	0.300	8	CARRIED	6
200083	2	4	1	5.655	46	CARRIED	1
200050	2	4	1	3.736	47	CARRIED	2
200145	2	4	1	3.235	47	CARRIED	3
200007	2	4	1	2.320	47	CARRIED	4
				1.943	47	CARRIED	

CARGO TYPE 2

SER-NO.	PORT DEP	PORT ARR	TYPE	WEIGHT	ROW	ADDRESS COL	TIER

100525	1	4	2	9.975	10	7	5	CARRIED	CONTAINER
100404	1	4	2	4.820	10	7	5	CARRIED	CONTAINER
100135	1	4	2	3.071	11	7	5	CARRIED	CONTAINER
100044	1	4	2	2.464	11	7	6	CARRIED	CONTAINER
100786	1	4	2	0.917	10	2	5	CARRIED	CONTAINER
100923	1	4	2	0.300	10	2	6	CARRIED	CONTAINER

CARGO TYPE 3

SER-NO.	DEP	PCRT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100243	1	4	3	8.914	16	7	2	CARRIED	CONTAINER
100608	1	4	3	7.911	16	7	3	CARRIED	CONTAINER
100871	1	4	3	6.139	16	7	4	CARRIED	CONTAINER
100704	1	4	3	4.378	16	7	5	CARRIED	CONTAINER
100925	1	4	3	2.055	16	7	6	CARRIED	CONTAINER
100102	1	4	3	1.576	17	7	2	CARRIED	CONTAINER
100834	1	4	3	0.318	17	7	3	CARRIED	CONTAINER
200028	2	4	3	5.483	47	4	5	CARRIED	CONTAINER

CARGO TYPE 4

SER-NC.	DEP	PCRT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100831	1	4	4	7.916	18	7	2	CARRIED	CONTAINER
100076	1	4	4	6.263	18	7	3	CARRIED	CONTAINER
100827	1	4	4	3.754	18	7	4	CARRIED	CONTAINER
100368	1	4	4	3.382	18	7	5	CARRIED	CONTAINER
100889	1	4	4	1.524	18	7	6	CARRIED	CONTAINER
100845	1	4	4	0.579	19	7	2	CARRIED	CONTAINER
200090	2	4	4	7.567	19	4	5	CARRIED	CONTAINER

CARGO TYPE 5

SER-NO.	DEP	PCRT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100366	1	4	5	9.960	30	7	5	CARRIED	CONTAINER

100363	1	4	5	8.031	30	7	6	CARRIED	CONTAINER
100092	1	4	5	4.939	31	7	5	CARRIED	CONTAINER
100049	1	4	5	4.185	31	7	5	CARRIED	CONTAINER
100611	1	4	5	1.602	30	2	5	CARRIED	CONTAINER
100719	1	4	5	0.455	30	2	6	CARRIED	CONTAINER
200040	2	4	5	9.382	47	4	6	CARRIED	CONTAINER

CARGO TYPE 6

SER-NO.	DEP	PORT	TYPE	WEIGHT	ADDRESS ROW COL TIER
100685	1	4	6	9.926	32 7 1
100464	1	4	6	8.714	32 7 2
100370	1	4	6	7.842	32 7 3
100875	1	4	6	6.748	32 7 4
100442	1	4	6	1.656	32 7 5
200030	2	4	6	1.354	32 4 2

CARGO TYPE 7

SER-NO.	DEP	PORT	TYPE	WEIGHT	ADDRESS ROW COL TIER
100653	1	4	7	8.908	38 7 1
100627	1	4	7	7.363	38 7 2
100072	1	4	7	4.699	38 7 3
100025	1	4	7	2.676	38 7 4

CARGO TYPE 8

SER-NO.	DEP	PORT	TYPE	WEIGHT	ADDRESS ROW COL TIER
100478	1	4	8	7.752	40 7 1
100521	1	4	8	5.666	40 7 2
100638	1	4	8	5.249	40 7 3
200066	2	4	8	6.705	40 4 1
200112	2	4	8	6.423	40 4 2
200128	2	4	8	2.086	40 4 3

[illegible]

CARRIED CARRIED CARRIED CARRIED CARRIED CARRIED CARRIED CARRIED CARRIED CARRIED
CONTAINER CONTAINER CONTAINER CONTAINER CONTAINER CONTAINER CONTAINER CONTAINER CONTAINER CONTAINER

MANIFEST OF CARGO CONTAINERS TO PORT NO.3
ORDER OF LOADING PORT ON THE ROUTE: 2

CARGO TYPE 1

SER-NO.	PCRT DEP ARR	TYPE	WEIGHT	ADDRESS ROW COL TIER
100433	1	1	9.451	7
100782	1	1	9.316	7
100162	1	1	9.091	7
100789	1	1	8.500	7
100205	1	1	8.264	7
100877	1	1	7.958	8
100820	1	1	7.805	8
100249	1	1	7.350	8
100311	1	1	6.599	8
100823	1	1	5.695	8
100274	1	1	5.324	9
100854	1	1	5.102	9
100022	1	1	4.508	9
100117	1	1	4.640	9
100734	1	1	4.547	9
100077	1	1	4.189	7
100472	1	1	3.969	7
100659	1	1	3.551	7
100840	1	1	3.488	7
100868	1	1	2.844	7
100180	1	1	2.758	7
100291	1	1	2.490	8
100141	1	1	2.150	8
100296	1	1	1.796	8
100697	1	1	1.668	8
100674	1	1	1.342	9
200098	1	1	0.774	9
200156	2	1	3.076	48
200003	2	1	2.474	48
			0.567	48
CARGO TYPE 2				
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100929	1	3	2	9.180	10	3	5	CARRIED	CONTAINER
100710	1	3	2	8.636	10	3	5	CARRIED	CONTAINER
100475	1	3	2	5.680	11	3	5	CARRIED	CONTAINER
100385	1	3	2	5.406	11	3	5	CARRIED	CONTAINER
100234	1	3	2	0.300	10	5	5	CARRIED	CONTAINER
200081	2	3	2	1.066	48	4	5	CARRIED	CONTAINER

CARGO TYPE 3

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100624	1	3	3	3	7.524	16	3	3	2
100583	1	3	3	3	7.135	16	3	3	3
100094	1	3	3	3	6.814	16	3	3	4
100667	1	3	3	3	6.779	16	3	3	5
100614	1	3	3	3	6.040	16	3	3	6
100342	1	3	3	3	4.226	17	3	3	2
100040	1	3	3	3	0.537	17	3	3	3
200065	2	3	3	3	2.886	48	4	4	4

CARGO TYPE 4

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100303	1	3	4	4	7.368	18	6	6	6
100349	1	3	4	4	6.474	19	6	6	2
100920	1	3	4	4	3.368	19	6	6	3
100601	1	3	4	4	3.180	19	6	6	4
100691	1	3	4	4	1.384	19	6	6	5
200136	2	3	4	4	9.733	48	4	4	6
200132	2	3	4	4	3.221	49	4	4	1

CARGO TYPE 5

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	ADDRESS	COL	TIER
100455	1	3	5	5	8.936	30	6	6	5

CARRIED CONTAINER

SER-NO.	100607	1	3	5	5.797	30	6	6	CARRIED	CONTAINER
	100508	1	3	5	4.807	31	6	5	CARRIED	CONTAINER
	100018	1	3	5	1.183	31	6	5	CARRIED	CONTAINER
	100663	1	3	5	1.112	30	3	5	CARRIED	CONTAINER

CARGO TYPE 6

SER-NO.	DEP	ARR	PORT	TYPE	WEIGHT	ADDRESS ROW	COL	TIER
100744	1	3	3	6	7.664	32	6	1
100124	1	3	3	6	5.886	32	6	2
100767	1	3	3	6	2.005	32	6	3
100036	1	3	3	6	1.503	32	6	4
100883	1	3	3	6	1.009	32	6	5
100439	1	3	3	6	0.300	32	6	6
200086	1	3	3	6	7.266	49	4	2

CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER

CARGO TYPE 7

SER-NO.	DEP	ARR	PORT	TYPE	WEIGHT	ADDRESS ROW	COL	TIER
100381	1	3	3	7	7.162	38	6	1
100602	1	3	3	7	6.879	38	6	2
100015	1	3	3	7	6.362	38	6	3
100841	1	3	3	7	5.844	38	6	4
100428	1	3	3	7	5.264	38	6	5
100620	1	3	3	7	5.222	38	6	6
100556	1	3	3	7	4.857	39	6	1
100248	1	3	3	7	4.077	39	6	2
100928	1	3	3	7	0.802	39	6	3
200107	1	3	3	7	6.261	49	4	3

CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER
CARRIED	CONTAINER

SER-NO.	DEP	ARR	PORT	TYPE	WEIGHT	ADDRESS ROW	COL	TIER
100048	1	3	3	8	9.906	40	6	1

CARRIED	CONTAINER
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100732	1	3	8	6.331	40	6	2	CARRIED	CONTAINER
100144	1	3	8	4.056	40	6	3	CARRIED <td>CONTAINER</td>	CONTAINER
100914	1	3	8	2.900	40	6	4	CARRIED <td>CONTAINER</td>	CONTAINER
100045	1	3	8	2.069	40	6	5	CARRIED <td>CONTAINER</td>	CONTAINER
100114	1	3	8	1.567	40	6	6	CARRIED <td>CONTAINER</td>	CONTAINER

ADDRESS
ROW COL TIER

SER-NO.	DEP	PORT	ARR	TYPE	WEIGHT	ROW	COL	TIER	CARRIED	CONTAINER
100555	1	3	3	9	9.940	19	6	6	CARRIED <td>CONTAINER</td>	CONTAINER
100458	1	3	3	9	9.805	30	6	1	CARRIED <td>CONTAINER</td>	CONTAINER
100912	1	3	3	9	9.803	30	6	2	CARRIED <td>CONTAINER</td>	CONTAINER
100451	1	3	3	9	9.796	30	6	3	CARRIED <td>CONTAINER</td>	CONTAINER
100026	1	3	3	9	9.760	30	6	4	CARRIED <td>CONTAINER</td>	CONTAINER
100892	1	3	3	9	9.649	31	6	1	CARRIED <td>CONTAINER</td>	CONTAINER
100780	1	3	3	9	9.431	31	6	2	CARRIED <td>CONTAINER</td>	CONTAINER
100350	1	3	3	9	9.402	31	6	3	CARRIED <td>CONTAINER</td>	CONTAINER
100240	1	3	3	9	9.358	33	6	4	CARRIED <td>CONTAINER</td>	CONTAINER
100330	1	3	3	9	9.222	33	6	1	CARRIED <td>CONTAINER</td>	CONTAINER
100473	1	3	3	9	9.222	33	6	2	CARRIED <td>CONTAINER</td>	CONTAINER
100470	1	3	3	9	9.216	33	6	3	CARRIED <td>CONTAINER</td>	CONTAINER
100295	1	3	3	9	9.195	33	6	4	CARRIED <td>CONTAINER</td>	CONTAINER
100733	1	3	3	9	9.169	33	6	5	CARRIED <td>CONTAINER</td>	CONTAINER
100739	1	3	3	9	9.064	33	6	6	CARRIED <td>CONTAINER</td>	CONTAINER
100009	1	3	3	9	9.059	39	6	4	CARRIED <td>CONTAINER</td>	CONTAINER
100501	1	3	3	9	9.033	39	6	5	CARRIED <td>CONTAINER</td>	CONTAINER
100279	1	3	3	9	9.014	39	6	6	CARRIED <td>CONTAINER</td>	CONTAINER
100461	1	4	1	9	8.006	41	6	1	CARRIED <td>CONTAINER</td>	CONTAINER
100160	1	4	1	9	8.977	41	6	2	CARRIED <td>CONTAINER</td>	CONTAINER
100402	1	4	1	9	8.658	41	6	3	CARRIED <td>CONTAINER</td>	CONTAINER
100467	1	4	1	9	8.629	41	6	4	CARRIED <td>CONTAINER</td>	CONTAINER
100492	1	4	1	9	8.543	41	6	5	CARRIED <td>CONTAINER</td>	CONTAINER
100221	1	4	1	9	8.536	46	6	6	CARRIED <td>CONTAINER</td>	CONTAINER
100078	1	4	1	9	8.534	46	6	1	CARRIED <td>CONTAINER</td>	CONTAINER
100182	1	4	1	9	8.534	46	6	2	CARRIED <td>CONTAINER</td>	CONTAINER
100836	1	4	1	9	8.480	46	6	3	CARRIED <td>CONTAINER</td>	CONTAINER
100706	1	4	1	9	8.378	46	6	4	CARRIED <td>CONTAINER</td>	CONTAINER

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SUMMARY MANIFEST

LIST OF LABELED CONTAINERS NOT IN SEPARATE HOLD.

SER-NO.	PORT DEP	ARR	TYPE	WEIGHT	ROW	ADDRESS COL	TIER
200146	2	4	1	5.655	46	4	6
200083	2	4	1	3.736	47	4	1
200050	2	4	1	3.235	47	4	2
200098	2	3	1	3.076	48	4	1
200156	2	3	1	2.474	48	4	2
200145	2	4	1	2.320	47	4	3
200007	2	4	1	1.943	47	4	4
200003	2	3	1	1.567	48	4	3
200081	2	3	2	1.066	48	4	5
200028	2	4	3	1.483	47	4	5
200065	2	3	3	2.886	48	4	4
200136	2	3	3	2.733	48	4	6
200132	2	3	4	3.221	49	4	1
200040	2	4	4	3.382	47	4	6
200130	2	5	5	3.884	46	4	5
200086	2	3	5	7.266	49	4	2
200107	2	3	7	6.261	49	4	3

NOTE:

IT MIGHT NOT BE APPROPRIATE TO STOW THESE CONTAINERS AT THOSE LOCATIONS.
RULES ON LABELED CARGO SHOULD BE CHECKED FOR EACH CONTAINER.

LIST OF CONTAINERS THAT HAVE NOT BEEN LOADED

ADDRESS
ROW COL TIER

SER-NO.	DEP	PORT ARR	TYPE	WEIGHT
200142	2	3	9	6.215
200022	2	3	9	6.162
200047	2	3	9	4.464
200137	2	3	9	4.339
200099	2	3	9	3.872
200013	2	3	9	3.231
200072	2	3	9	2.151
200094	2	3	9	1.837
200117	2	3	9	1.577
200015	2	3	9	0.641
200059	2	3	9	0.635
200114	2	3	9	0.300

UNOCCUPIED ADDRESSES AND ORDER OF CALL PORT OF CARGO
OF CARGO PARTIALLY OCCUPYING THE STACK

30	4	1	4
30	4	2	4
30	4	3	4
30	4	4	4
31	4	1	4
31	4	2	4
31	4	3	4
31	4	4	4
46	4	1	4
46	4	2	4
46	4	3	4
46	4	4	4

TRIM CALCULATION.

FORWARD DRAFT	AFT-DRAFT	MEAN	TOTAL WEIGHT
28.427	9.893	19.165	8532.582
WATER ADDED TO AFT-PALLAST TO KEEP SHIP TRIM EQUAL			ZERO 107.377TONS

COMPUTER PROGRAM
MAIN

```

COMMON/C1/K,L,JC,JR,JT,KRORIG,MTIER,MAXCOL,MLOWER,MAC,MAXROW(10),
1 LOG(10,60,10)
COMMON/C2/NCONT,ISER(3000),IPDEP(3000),IPARR(3000),ITYPE(3000),
1 WEIGHT(3000),ICOL(3000),IROW(3000),ITIER(3000)
COMMON /C3/ DISP,DRAAFT,DRAFWD,SHMEAN,SHLGTH,W,CL,SHMTI,A,T,DIFF,
1 Y,AA,AB,AC,AD,AE,AF,AG,AH,AI,AJ,BA,BB,BC,BD,BE,BF,BG,BH,BI,BJ,
1 CA,CB,CC,CD,CE,CF,CG,CH,CI,CJ,D,BAL1,BAL2, MOMT,WATER
1 READ(8,100)MAXCOL,MTIER,NCONT,NP,NLOADP ,MLOWER
1 READ(8,100)(MAXROW(I),I=1,9)
FCRMMAT(1015)
100 READ(8,105)(ISER(I),IPDEP(I),IPARR(I),ITYPE(I),WEIGHT(I),
1 IROW(I),ICOL(I),ITIER(I),I=1,NCONT)
105 FORMAT(1110,315,F10.3,110,215)
110 FORMAT(1110,315,F10.3,110,215)
115 FORMAT(10F8.2)
1 READ(5,115)DISP,DRAAFT,DRAFWD,SHMEAN,SHLGTH,CL,D,BAL1,BAL2
1 READ(5,115)AA,AB,AC,AD,AE,AF,AG,AH,AI,AJ
1 READ(5,115)BA,BB,BC,BD,BE,BF,BG,BH,BI,BJ
1 READ(5,115)CA,CB,CC,CD,CE,CF,CG,CH,CI,CJ
C*****SORT CONTAINERS INTO DECREASING WEIGHT ORDER.
C
C CALL SORT
C
C*****INITIALIZATON.
C
C DO 1 I=1,10
C DO 1 J=1,60
C DO 1 K=1,10
C LOG(I,J,K) =0
C 1 CONTINUE
C
C*****REGISTER THE ADDRESSES OF OCCUPIED LOCATIONS.
C
C DO 2 I=1,NCONT
C IF(IROW(I).EQ.0)GO TO 2
C JC=ICOL(I)
C JR=IROW(I)
C JT=ITIER(I)
C LCG(JC,JR,JT)=IPARR(I)-(NLOADP-1)
C IF(LOG(JC,JR,JT).LE.0)LOG(JC,JR,JT)=NP+LOG(JC,JR,JT)
C IF(IPARR(I).EQ.0) LOG(JC,JR,JT)=NP
C 2 CONTINUE
C
C*****DETERMINE THE MIDDLE COLUMN NUMBER.
C
C MAC=MAXCOL/2
C IF(MAC.NE.FLOAT(MAXCOL)/2.)MAC=(MAXCOL+1)/2

```



```

C *****GROUP CONTAINERS INTO PORT OF DESTINATION.
C
N1=NP-1
DO 6 J=1,N1
K=NP-J+1
NARRP=K+NLOADP-1
IF(NARRP.GT.NP)NARRP=NARRP-NP
WRITE(6,120)NARRP
FORMAT(1)
MANIFEST OF CARGO CONTAINERS TO PORT NO.,111)
120 WRITE(6,125)NLOADP
125 FORMAT('0',12X,'ORDER OF LOADING PORT ON THE ROUTE: ',11)
C *****GROUP OF CONTAINERS INTO SPECIAL TYPES.
C
DO 6 L=1,9
KRORIG=0
DO 4 N=1,L
KRORIG=KRORIG+MAXROW(N)
JR=KRORIG-MAXROW(L)
IF(L.EQ.9)JR=0
JC=MAXCOL
JT=MTIER
WRITE(6,130) L
FORMAT(1)
130
135 WRITE(6,135)
FORMAT(1)
PORT
140 WRITE(6,140)
FORMAT(1)
SER-NO. DEP ARR TYPE WEIGHT ADDRESS
WRITE(6,110)
ROW COL TIER
C *****PRINT OUT THE ADDRESSES OF CARRIED CONTAINERS.
C
DO 5 M=1,NP
DO 5 I=1,NCONT
IF(IPDEP(I).NE.M) GO TO 5
IF(ITYPE(I).NE.L) GO TO 5
IF(IPARR(I).NE.NAKRP)GO TO 5
IF(IROW(I).EQ.0) GO TO 5
WRITE(6,110)ISER(I),IPDEP(I),IPARR(I),ITYPE(I),WEIGHT(I),
1 IROW(I),ICOL(I),ITIER(I)
WRITE(6,150)
FORMAT('+',60X,'CARRIED CONTAINER')
150 W=WEIGHT(I)
A=FLOAT(IROW(I))
CALL TRIM
5 CONTINUE
C

```


C*****ASSIGN ADDRESSES FOR NEW CONTAINERS.
C

```

DO 6 I=1,NCONT
  IF(ITYPE(I).NE.L) GO TO 6
  IF(IPARR(I).NE.NARRP)GO TO 6
  IF(IROW(I).NE.O) GO TO 6
  CALL POST
  IF(JT.EQ.(MTIER+1)) GO TO 6
  ICOL(I)=JC
  IROW(I)=JR
  ITIER(I)=JT
  WRITE(6,110)ISER(I),IPDEP(I),IPARR(I),ITYPE(I),WEIGHT(I),
1 IROW(I),ICOL(I),ITIER(I)
  W=WEIGHT(I)
  A=FLOAT(IROW(I))
  CALL TRIM
6 CONTINUE

```

C*****LIST OF LABELED CONTAINERS WHICH ARE NOT STOWED IN RESERVED HOLDS.
C

```

500 WRITE(6,500)
185 FORMAT(1,35X,'SUMMARY MANIFEST')
  FORMAT(0,20X,'LIST OF LABELED CONTAINERS NOT IN SEPARATE HOLD.')
  WRITE(6,185)
  WRITE(6,135)
  WRITE(6,140)
  WRITE(6,110)
  KRORIG=0
  DO 7 L=1,9
    KRORIG=KRORIG+MAXROW(L)
  DO 7 I=1,NCONT
    IF(ITYPE(I).NE.L) GO TO 7
    IF(IROW(I).LE.KRORIG) GO TO 7
    WRITE(6,110)ISER(I),IPDEP(I),IPARR(I),ITYPE(I),WEIGHT(I),
1 IROW(I),ICOL(I),ITIER(I)
7 CONTINUE

```

```

195 WRITE(6,195)
  FORMAT(0,5X,'NOTE: IT MIGHT NOT BE APPROPRIATE TO STOW THESE
1 CONTAINERS AT THOSE LOCATIONS.')
  WRITE(6,200)
200 FORMAT(15X,'RULES ON LABELED CARGO SHOULD BE CHECKED FOR EACH CONT
1AINER.')
  WRITE(6,110)

```

C*****LIST OF CONTAINERS THAT HAVE NOT BEEN LOADED WITHOUT OVERSTOW.
C

```

170 WRITE(6,170)
  FORMAT(0,20X, 'LIST OF CONTAINERS THAT HAVE NOT BEEN LOADED')

```



```

WRITE(6,135)
WRITE(6,140)
WRITE(6,110)
DO 9 J=1,NCONT
9 IF(IROW(J).EQ.0)WRITE(6,110)ISER(J),IPARR(J),IPARR(J),ITYPE(J)
1,WEIGHT(J)
WRITE(6,110)

C*****LIST OF UNOCCUPIED ADDRESSES.
C
WRITE(6,110)
WRITE(6,175)
WRITE(6,176)
FORMAT(20X,'UNOCCUPIED ADDRESSES AND ORDER OF CALL PORT OF CARGO')
FORMAT(27X,'OF CARGO PARTIALLY OCCUPYING THE STACK')
WRITE(6,110)
DO 11 I=1,MAXCOL
DO 11 J=1,KRORIG
DO 11 K=1,MTIER
JL=MLOWER+1
11 IF(LOG(I,J,K).EQ.0)WRITE(6,180)J,I,K,LOG(I,J,JL)
180 WRITE(6,110)
WRITE(6,110)
WRITE(6,205)
FORMAT(10,'30X','TRIM CALCULATION.')
WRITE(6,210)
FORMAT(10,'10X','FORWARD DRAFT AFT-DRAFT MEAN TOTAL
1L WEIGHT')
WRITE(6,220)DRAFW,DRAAFT,SHMEAN,DISP
FORMAT(10,'10X,5(F10.3,5X))
IF(MOMI.GT.0)WRITE(6,510)WATER
IF(MOMT.LE.0)WRITE(6,520)WATER
510 FORMAT(10,'WATER ADDED TO FWD-BALLAST TO KEEP SHIP TRIM EQUAL ZERO
10',F10.3,' TONS')
520 FORMAT(10,'WATER ADDED TO AFT-BALLAST TO KEEP SHIP TRIM EQUAL ZERO
10',F10.3,' TONS')
END

```



```

SUBROUTINE SORT
COMMON/C2/NCONT, ISER(3000), IPDEP(3000), IPARR(3000), ITYPE(3000),
1 WEIGHT(3000), ICOL(3000), IROW(3000), ITIER(3000)
NC=NCONT-1
DO 1 I=1,NC
  I1=I+1
  DO 1 J=I1,NCONT
    IF (WEIGHT(J).LE.WEIGHT(I)) GO TO 1
    WES=WEIGHT(I)
    WEIGHT(I)=WEIGHT(J)
    WEIGHT(J)=WES
    ISERS=ISER(I)
    ISER(I)=ISER(J)
    ISER(J)=ISERS
    IPDEPS=IPDEP(I)
    IPDEP(I)=IPDEP(J)
    IPDEP(J)=IPDEPS
    IPARRS=IPARR(I)
    IPARR(I)=IPARR(J)
    IPARR(J)=IPARRS
    ITPES=ITYPE(I)
    ITYPE(I)=ITYPE(J)
    ITYPE(J)=ITPES
    ICOLS=ICOL(I)
    ICOL(I)=ICOL(J)
    ICOL(J)=ICOLS
    IROWS=IROW(I)
    IROW(I)=IROW(J)
    IROW(J)=IROWS
    ITIERS=ITIER(I)
    ITIER(I)=ITIER(J)
    ITIER(J)=ITIERS
  1 CONTINUE
  RETURN
END

```



```

SUBROUTINE POST
COMMON/C1/K,L,JC,JR,JT,KRORIG,MTIER,MAXCOL,MLOWER,MAC,MAXROW(10),
1 LOG(10,60,10)
1 IF(JT.NE.MTIER) GO TO 4
1 IF(JC.NE.MAC) GO TO 4
1 IF(JR.NE.KRORIG) GO TO 4
2 JT=MTIER+1
1 IF(L.EQ.9) RETURN
KRORIG=0
DO 3 N=1,9
3 KRORIG=KRORIG+MAXROW(N)
JR=KRORIG-MAXROW(9)
GO TO 1
4 JT=JT+1
1 IF(JT.LE.MTIER) GO TO 5
JT=1
JR=JR+1
1 IF(JR.LE.KRORIG) GO TO 5
JR=KRORIG-MAXROW(L)
1 IF(L.EQ.9) JR=0
JT=MTIER
INC=JC
JC=MAXCOL-INC
1 IF(INC.GE.MAXCOL/2) JC=MAXCOL-(INC-1)
GO TO 1
5 JL=MLOWER+1
1 IF(LOG(JC,JR,JT).NE.0) GO TO 1
1 IF(((JT.LE.MLOWER).AND.((L.EQ.2).OR.(L.EQ.5)))) GO TO 1
1 IF((LOG(JC,JR,JL).NE.0).AND.(K.LT.LOG(JC,JR,JL)).AND.((JT.LE.MLOWER
1)) GO TO 1
1 IF(LOG(JC,JR,1).EQ.0) GO TO 6
1 IF(LOG(JC,JR,1).LT.K) GO TO 1
6 LOG(JC,JR,JT)=K
RETURN
END

```



```

SUBROUTINE TRIM
COMMON /C3/ DISP,DRAAFT,DRAAFWD,SHMEAN,SHLGTH,W,CL,SHMTI,A,T,DIFF,
1 Y,AA,AB,AC,AD,AE,AF,AG,AH,AI,AJ,BA,BB,BC,BD,BE,BF,BG,BH,BI,BJ,
1 CA,CB,CC,CD,CE,CF,CG,CH,CI,CJ,D,BAL1,BAL2,MOMT,WATER
DISP=DISP+W
CALL CURVE(Y,DISP,AA,AB,AC,AD,AE,AF,AG,AH,AI,AJ,BA,BB,BC,BD,BE,BF,
1 BG,BH,BI,BJ)
DIFF=Y-SHMEAN
CALL CURVE(SHMTI,DISP,AA,AB,AC,AD,AE,AF,AG,AH,AI,AJ,CA,CB,CC,CD,CE
1 CF,CG,CH,CI,CJ)*CL-D)*W/SHMTI
t=((A-SHLGTH/2.)*CL-D)*W/SHMTI
DRAAFT=DRAAFT+DIFF-T/2.
DRAAFWD=DRAAFWD+DIFF+T/2.
SHMEAN=SHMEAN+DIFF
ADJ=DRAAFT-DRAAFWD
MOMT=ADJ*SHMTI
IF(MOMT.GT.0)WATER=MOMT/(BAL2-SHLGTH*CL/2.-D)
IF(MOMT.LE.0)WATER=MOMT/(BAL1-SHLGTH*CL/2.+D)
RETURN
END

```



```

SUBROUTINE CURVE(Y,X,X0,X1,X2,X3,X4,X5,X6,X7,X8,X9,Y0,Y1,Y2,Y3,Y4,
1 Y5,Y6,Y7,Y8,Y9)
  IF(X.LT.X1) Y=Y0+(Y1-Y0)/(X1-X0)*(X-X0)
  IF((X.GE.X1).AND.(X.LT.X2)) Y=Y1+(Y2-Y1)/(X2-X1)*(X-X1)
  IF((X.GE.X2).AND.(X.LT.X3)) Y=Y2+(Y3-Y2)/(X3-X2)*(X-X2)
  IF((X.GE.X3).AND.(X.LT.X4)) Y=Y3+(Y4-Y3)/(X4-X3)*(X-X3)
  IF((X.GE.X4).AND.(X.LT.X5)) Y=Y4+(Y5-Y4)/(X5-X4)*(X-X4)
  IF((X.GE.X5).AND.(X.LT.X6)) Y=Y5+(Y6-Y5)/(X6-X5)*(X-X5)
  IF((X.GE.X6).AND.(X.LT.X7)) Y=Y6+(Y7-Y6)/(X7-X6)*(X-X6)
  IF((X.GE.X7).AND.(X.LT.X8)) Y=Y7+(Y8-Y7)/(X8-X7)*(X-X7)
  IF((X.GE.X8).AND.(X.LT.X9)) Y=Y8+(Y9-Y8)/(X9-X8)*(X-X8)
  IF(X.GE.X9) Y=Y9
  RETURN
END

```


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